

We claim:

1. A method for fabricating a CPP spin valve structure, comprising:
  - (a) providing a substrate and depositing an oxygen doped seed layer thereon;
  - (b) depositing an oxygen doped AFM layer on said oxygen doped seed layer;
  - (c) depositing a synthetic anti-parallel (SyAP) pinned layer on said oxygen doped AFM layer wherein said SyAP pinned layer is a composite layer formed by sequentially depositing a non-oxygen doped pinned layer, a coupling layer, and an oxygen doped pinned layer;
  - (d) depositing a copper spacer on the SyAP pinned layer;
  - (e) depositing an oxygen doped free layer above the copper spacer; and
  - (f) depositing a copper layer on the oxygen doped free layer and a capping layer on the copper layer.
2. The method of claim 1 wherein all layers in said CPP spin valve structure are sputter deposited in an ultra-high vacuum system having a base pressure less than about  $1 \times 10^{-8}$  torr.
3. The method of claim 1 wherein the oxygen doped seed layer, oxygen doped AFM layer, oxygen doped pinned layer, and oxygen doped free layer are sputter deposited with an oxygen doped Ar gas.
4. The method of claim 3 wherein the oxygen doped Ar gas has a pressure of less than 0.5 mtorr with an oxygen partial pressure between about  $1 \times 10^{-9}$  and  $1 \times 10^{-8}$  torr.
5. The method of claim 1 further comprised of forming an oxygen surfactant layer having a thickness of less than about one atomic layer on the copper spacer layer before depositing the oxygen doped free layer.

6. The method of claim 1 wherein the oxygen doped free layer, copper spacer layer, and the oxygen doped pinned layer are made thicker to increase bulk scattering.
7. The method of claim 1 wherein the SyAP pinned layer is comprised of:
  - (a) a non-oxygen doped AP2 CoFe layer which is sputter deposited using a conventional Ar sputter gas and having a thickness of about 20 to 30 Angstroms on said oxygen doped AFM layer;
  - (b) an oxygen doped Ru coupling layer having a thickness of about 7.5 Angstroms on the AP2 CoFe layer; and
  - (c) an oxygen doped AP1 CoFe layer with a thickness of about 25 to 35 Angstroms on the oxygen doped Ru coupling layer
8. The method of claim 7 further comprised of forming an insertion layer in said oxygen doped AP1 CoFe layer to increase interfacial scattering.
9. The method of claim 8 wherein the insertion layer is a nano-oxide layer with a thickness of about 2 to 3 Angstroms comprised of FeTaO or CoFeO.
10. The method of claim 8 wherein the insertion layer is a dusting of Cu, Ta, or NiCr that has a thickness of between 1 and 3 Angstroms.
11. The method of claim 1 wherein the oxygen doped free layer is comprised of a CoFe layer with a thickness of about 5 to 10 Angstroms and a NiFe layer with a thickness between about 30 and 40 Angstroms on said CoFe layer and wherein the oxygen doped AFM layer is comprised of MnPt with a thickness of about 125 to 175 Angstroms.
12. The method of claim 1 wherein the capping layer is a 30 to 50 Angstrom thick film of Ta.

13. The method of claim 1 wherein oxygen doped AFM layer has an exchange bias strength that is increased by increasing the oxygen dopant concentration and wherein increasing the exchange bias strength makes a thicker SyAP pinned layer viable.

14. The method of claim 1 wherein said oxygen doped free layer and said oxygen doped pinned layer have thicknesses that are increased to compensate for a lower magnetic moment caused by the oxygen dopant.

15. The method of claim 14 wherein the CPP spin valve structure has a resistance RA and magnetoresistive (MR) ratio that is increased by increasing the oxygen partial pressure in the range of  $1 \times 10^{-9}$  to  $1 \times 10^{-8}$  torr.

16. The method of claim 1 further comprised of annealing said CPP spin valve structure.

17. A method for fabricating a CPP dual spin valve structure, comprising:

- (a) providing a substrate and depositing an oxygen doped seed layer thereon;
- (b) depositing a first oxygen doped AFM layer on said oxygen doped seed layer;
- (c) depositing a first SyAP pinned layer on said first oxygen doped AFM layer wherein said first SyAP pinned layer is a composite layer formed by sequentially depositing a non-oxygen doped pinned layer, a coupling layer, and an oxygen doped pinned layer;
- (d) depositing a copper spacer on the first SyAP pinned layer;
- (e) depositing an oxygen doped free layer above the copper spacer;
- (f) depositing a second copper spacer on the oxygen doped free layer;
- (g) depositing a second SyAP pinned layer on the second copper spacer wherein said second SyAP pinned layer is a composite layer formed by sequentially

depositing an oxygen doped pinned layer, a coupling layer, and a non-oxygen doped pinned layer; and

(h) depositing a second oxygen doped AFM layer on the second SyAP pinned layer and a capping layer on the second oxygen doped AFM layer.

18. The method of claim **17** wherein all layers in said CPP dual spin valve structure are sputter deposited in an ultra-high vacuum system having a base pressure less than about  $1 \times 10^{-8}$  torr.

19. The method of claim **18** wherein the oxygen doped layers are sputter deposited with an oxygen doped Ar gas.

20. The method of claim **19** wherein the oxygen doped Ar gas has a pressure of less than 0.5 mtorr with an oxygen partial pressure between about  $1 \times 10^{-9}$  and  $1 \times 10^{-8}$  torr.

21. The method of claim **17** further comprised of forming an oxygen surfactant layer having a thickness of less than about one atomic layer between the first copper spacer and the oxygen doped free layer and between the second copper spacer and the second SyAP pinned layer.

22. The method of claim **17** wherein the oxygen doped free layer, the first and second copper spacers, and oxygen doped pinned layers are made thicker to increase bulk scattering.

23. The method of claim **17** wherein the first SyAP pinned layer is comprised of:

(1) a non-oxygen doped AP2 CoFe layer with a thickness of about 20 to 30 Angstroms on said first oxygen doped AFM layer;

(2) a first oxygen doped Ru coupling layer having a thickness of about 7.5 Angstroms on the AP2 CoFe layer; and

(3) an oxygen doped AP1 CoFe layer with a thickness of about 25 to 35 Angstroms on the first oxygen doped Ru coupling layer,

and wherein the second SyAP pinned layer is comprised of:

(1) an oxygen doped AP3 CoFe layer with a thickness of about 25 to 35 Angstroms above said second copper spacer;

(2) a second oxygen doped Ru coupling layer having a thickness of about 7.5 Angstroms on the oxygen doped AP3 CoFe layer; and

(3) a non-oxygen doped AP4 CoFe layer with a thickness of about 20 to 30 Angstroms on the second oxygen doped Ru coupling layer.

24. The method of claim **23** further comprised of forming an insertion layer in one or more of said oxygen doped AP1 CoFe layer, said oxygen doped AP3 CoFe layer, said oxygen doped free layer, and said first and second copper spacers to increase interfacial scattering.

25. The method of claim **24** wherein the insertion layer is a nano-oxide layer with a thickness of about 2 to 3 Angstroms comprised of FeTaO or CoFeO.

26. The method of claim **24** wherein the insertion layer is a dusting of Cu, Ta, or NiCr that has a thickness of between 1 and 3 Angstroms.

27. The method of claim **17** wherein the oxygen doped free layer is comprised of a bottom CoFe layer with a thickness of about 5 to 10 Angstroms, a middle NiFe layer with a thickness of about 30 to 40 Angstroms, and an upper CoFe layer with a thickness of about 5 to 10 Angstroms.

28. The method of claim **17** wherein the first oxygen doped AFM layer is comprised of MnPt with a thickness of about 125 to 175 Angstroms and the second oxygen doped AFM layer is comprised of MnPt with a thickness of about 150 to 200 Angstroms.

29. The method of claim **17** wherein the capping layer is a 30 to 50 Angstrom thick film of Ta.

30. The method of claim **17** wherein first and second oxygen doped AFM layers have an exchange bias strength that is increased by increasing the oxygen dopant concentration and wherein increasing the exchange bias strength makes thicker first and second SyAP pinned layers viable.

31. The method of claim **17** wherein said oxygen doped free layer and said oxygen doped pinned layers have thicknesses that are increased to compensate for a lower magnetic moment caused by oxygen doping.

32. The method of claim **20** wherein the CPP dual spin valve structure has a resistance RA and magnetoresistive (MR) ratio that is increased by increasing the oxygen partial pressure in the range of  $1 \times 10^{-9}$  to  $1 \times 10^{-8}$  torr.

33. The method of claim **17** further comprised of annealing said CPP dual spin valve structure.

34. A CPP spin valve structure, comprising;

- (a) a substrate with an oxygen doped seed layer formed thereon;
- (b) an oxygen doped AFM layer on said oxygen doped seed layer;
- (c) an oxygen doped synthetic anti-parallel (SyAP) pinned layer on said oxygen doped AFM layer;
- (d) a copper spacer on the oxygen doped SyAP pinned layer;

(e) an oxygen doped free layer above the copper spacer; and

(f) a copper layer on the oxygen doped free layer and a capping layer on the copper layer.

35. The CPP spin valve structure of claim **34** wherein the oxygen doped seed layer is comprised of NiCr and has a thickness of about 40 to 60 Angstroms.

36. The CPP spin valve structure of claim **34** wherein the oxygen doped AFM layer is comprised of MnPt and has a thickness of about 125 to 175 Angstroms.

37. The CPP spin valve structure of claim **34** wherein the oxygen doped SyAP pinned layer is comprised of:

(a) a non-oxygen doped AP2 CoFe layer with a thickness of about 20 to 30 Angstroms on said oxygen doped AFM layer;

(b) an oxygen doped Ru coupling layer having a thickness of about 7.5 Angstroms on the AP2 CoFe layer; and

(c) an oxygen doped AP1 CoFe layer with a thickness of about 25 to 35 Angstroms on the oxygen doped Ru coupling layer.

38. The CPP spin valve structure of claim **34** further comprised of an oxygen surfactant layer having a thickness of less than about 1 atomic layer formed between the copper spacer layer and the oxygen doped free layer.

39. The CPP spin valve structure of claim **37** further comprised of an insertion layer in one or more of said oxygen doped AP1 CoFe layer, said oxygen doped free layer, and said copper spacer.

40. The CPP spin valve of claim **39** wherein the insertion layer is a nano-oxide layer with a thickness of about 2 to 3 Angstroms comprised of FeTaO or CoFeO.

41. The CPP spin valve of claim **39** wherein the insertion layer is a dusting of Cu, Ta, or NiCr that has a thickness of between 1 and 3 Angstroms.

42. The CPP spin valve of claim **34** wherein the oxygen doped free layer is a composite layer comprised of a bottom CoFe layer with a thickness of about 5 to 10 Angstroms and an upper NiFe layer with a thickness of about 30 to 40 Angstroms.

43. The CPP spin valve of claim **34** wherein the capping layer is a 30 to 50 Angstrom thick film of Ta.

44. The CPP spin valve of claim **34** wherein the oxygen content in said oxygen doped layers is about 100 to 500 ppm.

45. A CPP dual spin valve structure, comprising:

- (a) a substrate with an oxygen doped seed layer formed thereon;
- (b) a first oxygen doped AFM layer on said oxygen doped seed layer;
- (c) a first SyAP pinned layer on said first oxygen doped AFM layer;
- (d) a first copper spacer on the first SyAP pinned layer;
- (e) an oxygen doped free layer above the first copper spacer;
- (f) a second copper spacer on the oxygen doped free layer;
- (g) a second SyAP pinned layer on the second copper spacer; and
- (h) a second oxygen doped AFM layer on the second SyAP pinned layer and a capping layer formed on the second oxygen doped AFM layer.

46. The CPP dual spin valve structure of claim **45** wherein the oxygen doped seed layer is comprised of NiCr and has a thickness of about 40 to 60 Angstroms.

47. The CPP dual spin valve structure of claim **45** wherein the first oxygen doped AFM layer is comprised of MnPt and has a thickness of about 125 to 175 Angstroms



and the second oxygen doped AFM layer is comprised of MnPt and has a thickness of about 150 to 200 Angstroms.

48. The CPP dual spin valve structure of claim **45** wherein the first oxygen doped SyAP pinned layer is comprised of:

(1) a non-oxygen doped AP2 CoFe layer with a thickness of about 20 to 30 Angstroms formed on said first oxygen doped AFM layer;

(2) a first oxygen doped Ru coupling layer having a thickness of about 7.5 Angstroms on the AP2 CoFe layer; and

(3) an oxygen doped AP1 CoFe layer with a thickness of about 25 to 35 Angstroms formed on the first oxygen doped Ru coupling layer,

and wherein the second oxygen doped SyAP pinned layer is comprised of:

(1) an oxygen doped AP3 CoFe layer with a thickness of about 25 to 35 Angstroms above said second copper spacer;

(2) a second oxygen doped Ru coupling layer having a thickness of about 7.5 Angstroms on the oxygen doped AP3 CoFe layer; and

(3) a non-oxygen doped AP4 CoFe layer with a thickness of about 20 to 30 Angstroms formed on the second oxygen doped Ru coupling layer.

49. The CPP dual spin valve structure of claim **45** further comprised of an oxygen surfactant layer having a thickness of less than about one atomic layer formed between the first copper spacer layer and the oxygen doped free layer and between the second copper spacer and the second oxygen doped SyAP pinned layer.

50. The CPP dual spin valve structure of claim **45** further comprised of an insertion layer formed in one or more of said oxygen doped AP1 CoFe layer, said oxygen doped

AP3 CoFe layer, said oxygen doped free layer, and said first and second copper spacers.

51. The CPP dual spin valve structure of claim **50** wherein the insertion layer is a nano-oxide layer with a thickness of about 2 to 3 Angstroms comprised of FeTaO or CoFeO.

52. The CPP dual spin valve structure of claim **50** wherein the insertion layer is a dusting of Cu, Ta, or NiCr that has a thickness between about 1 and 3 Angstroms.

53. The CPP dual spin valve structure of claim **45** wherein the oxygen doped free layer is a composite layer comprised of a bottom CoFe layer with a thickness of about 5 to 10 Angstroms, a middle NiFe layer with a thickness of about 30 to 40 Angstroms, and an upper CoFe layer with a thickness of about 5 to 10 Angstroms.

54. The CPP dual spin valve structure of claim **45** wherein the capping layer is a 30 to 50 Angstrom thick film of Ta.

55. The CPP spin valve structure of claim **45** wherein the oxygen content in said oxygen doped layers is about 100 to 500 ppm.